



DEPARTMENT OF THE AIR FORCE
59TH MEDICAL WING (AETC)
JOINT BASE SAN ANTONIO - LACKLAND TEXAS



15 MAR 2017

MEMORANDUM FOR 959 CSPS

ATTN: MAJ JAMES D COVELLI

FROM: 59 MDW/SGVU

SUBJECT: Professional Presentation Approval

1. Your paper, entitled **Diagnosis of Pediatric Appendicitis: Is MR Imaging More Appropriate than CT?** presented at/published to **Should Non-Contrast Rapid MRE Evaluation of Clinically Suspected Pediatric Appendicitis Trump CT after Equivocal Ultrasound? (No Publication Journal Assigned Yet) & American Roentgen Ray Society (ARRS), New Orleans, LA, 1-6 April 2017** in accordance with MDWI 41-108, has been approved and assigned local file #**17059**.
2. Pertinent biographic information (name of author(s), title, etc.) has been entered into our computer file. Please advise us (by phone or mail) that your presentation was given. At that time, we will need the date (month, day and year) along with the location of your presentation. It is important to update this information so that we can provide quality support for you, your department, and the Medical Center commander. This information is used to document the scholarly activities of our professional staff and students, which is an essential component of Wilford Hall Ambulatory Surgical Center (WHASC) internship and residency programs.
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4. Congratulations, and thank you for your efforts and time. Your contributions are vital to the medical mission. We look forward to assisting you in your future publication/presentation efforts.

LINDA STEEL-GOODWIN, Col, USAF, BSC
Director, Clinical Investigations & Research Support

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Abstract No:

16-077

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Author(s):

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Purpose:

In lieu of potential radiation risks associated with CT, MR imaging has become much more prevalent in the evaluation of children with suspected appendicitis. While several studies have demonstrated its efficacy at dedicated stand-alone pediatric hospitals, the goal of this study is to determine if implementation of a MR pediatric appendicitis protocol is feasible in the non-subspecialty pediatric setting, where non-pediatric radiologists routinely perform interpretation.

Materials/Methods Used:

Pediatric appendicitis work-up algorithm was implemented at the San Antonio Military Medical Center emergency department in 2012 (diagram 1). Non-sedated MR imaging was obtained in patients with equivocal ultrasound findings and persistent clinical concern for appendicitis. MR protocols consisted of three whole abdomen T2 sequences through the abdomen (average scan time 11 minutes). No intravenous contrast was administered. Between 2012 and 2015, 415 pediatric patients (mean age 9.8 years old) underwent MRI of the abdomen after equivocal ultrasound evaluation. Non-pediatric radiologists interpreted the vast majority of MR exams.

Results:

Over the three year period of data acquisition, 10.2% (44/432) of patients were found to have appendicitis after surgery. Of those patients with pathologically proven appendicitis, 42 were true positives and 2 were false negatives by MRI, resulting in sensitivity and specificity of 95% and 99%, respectively. Additionally, negative and positive predictive values by MRI were 99% and 89%, respectively. Both false negative exams were surgically confirmed early appendicitis without inflammatory changes by MR imaging. Several non-appendiceal abnormalities were also found by MRI, including ovarian pathology (7/432), pyelonephritis (5/432) and terminal ileitis (3/432).

Conclusions:

MRI is an effective imaging modality for the evaluation of pediatric appendicitis and can be accurately interpreted by non-pediatric radiologists. Because of the lack of ionizing radiation and IV contrast, non-sedated, rapid MRI may be considered more appropriate than CT in the pediatric population, which is at higher risk for radiation-induced malignancies and also has less tolerance for IV placement.

Primary Track/Category:

Quality and Safety

Secondary Track/Category:

Clinical Education

Area of Focus:

Diagnostic Radiology

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SAMMC

SAN ANTONIO MILITARY MEDICAL CENTER

Diagnosis of Pediatric Appendicitis: Is MR Imaging More Appropriate than CT?

San Antonio Military Medical Center
San Antonio, Texas

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Christian L Carlson, MD

DISCLOSURE

L

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MATERIALS AND METHODS

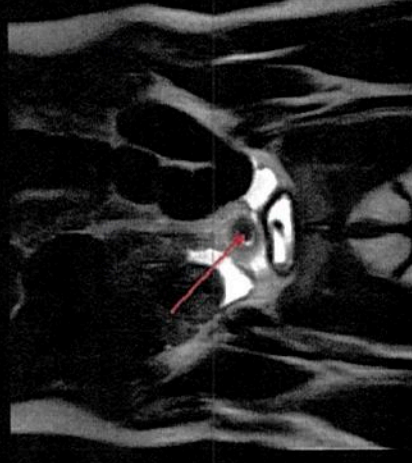
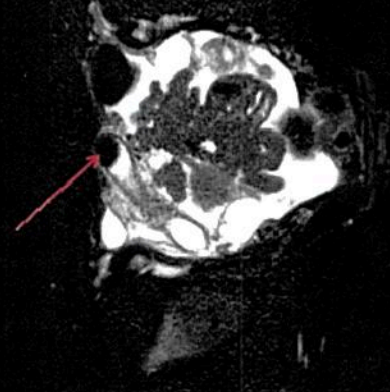
RESULTS

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Purpose

- Prospective and retrospective studies have shown sensitivity and specificity of MRI to be comparable to CT.
- In lieu of potential radiation risks associated with CT, MRI has increased in children with suspected appendicitis.
- Several studies have demonstrated MRI efficacy at stand-alone pediatric hospitals.

The purpose of our study is to determine if implementation of an MRI pediatric appendicitis protocol is feasible in the non-specialty pediatric setting where non-pediatric radiologists and residents routinely perform interpretation



10 year old female with perforated appendicitis
T2 Axial Fat Saturated image (left) and a coronal HASTE image (right) demonstrate a dilated fluid filled appendix with an appendicolith (arrow) and T2 hyperintense pelvic free fluid.

Suspected Appendicitis?

- In 2012, a pediatric appendicitis work-up algorithm was established for children aged 0-17 with suspected appendicitis in collaboration with SAMMC Radiology, Emergency Room, Pediatric Surgery, General Surgery and Pediatrics staff.
- Modifications were made to the algorithm to improve efficiency including:
 - Immediate ultrasound (US) review by radiologist
 - Orders for US and MRI were placed at the same time by the ER. If US was positive or clearly negative, the MRI order was cancelled
 - If equivocal US findings or non-visualization of the appendix, the patient was transported directly from US to MRI (instead of returning to the ER)
 - MRI scan time was reduced from 21 minutes to 11 minutes from 2012 to 2015 after determining the optimal sequences to arrive at diagnosis
- The latest algorithm (Figure 1) was implemented in 2015

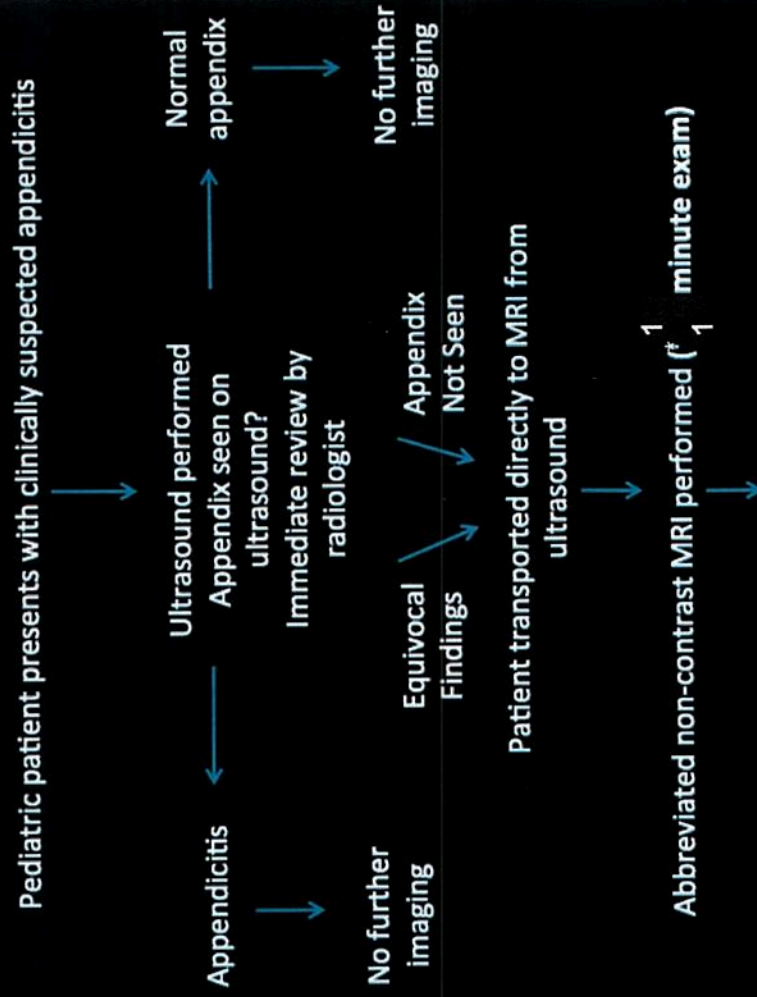


Figure 1. Current SAMMC algorithm for all children 0-17 years of age with suspected appendicitis.

* This time was reduced from 21 minutes (in 2012) to 16 minutes in 2015 after reducing the total number of MRI sequences. Exams that did not include restricted diffusion took 11 minutes)

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Rapid MRI Protocol

- A non-sedation MRI protocol was established using either 1.5T or 3T scanners and exams were worked in-between inpatient and scheduled outpatient exams.
- Multichannel torso coil was used
- Patient urinates prior to exam
- Technique for children ≥ 12 years
 - Breath hold
 - 4 mm slice thickness with 10% gap
- Technique for children < 12 years old
 - Free breathing
 - 3 mm slice thickness with 10% gap
- Trial sequences were found to have limited utility or did not add to or improve interpretation and were removed from our protocol:
 - In and out of Phase T1-weighted imaging
 - Sagittal and Coronal fat-saturation HASTE
 - VIBE
 - Diffusion-weighted MRI (DW-MRI)
 - TruFisp
 - SPARE

Current SAMMC Rapid Appendicitis Protocol (protocol finalized in 2015)

Axial T2-weighted fat saturated images

Axial half-Fourier acquisition single shot turbo spin echo
(HASTE)

Coronal half-Fourier acquisition turbo spin echo (HASTE)

Coronal HASTE FOV: Entire abdomen and pelvis
Axial HASTE and T2 FS FOV: Inferior endplate of L3
through the pubic floor

256 x 256 matrix

Figure 2. Current SAMMC rapid MRI appendix protocol

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Radiologist and Clinician Education

- Between 2012 and 2015, 506 patients under the age of 18 (mean age 9.8 years) with clinically suspected appendicitis, and equivocal findings or non-visualization of the appendix on ultrasound, underwent MRI of the abdomen using our rapid MRI appendix protocol
- The majority of exams were performed during overnight and weekend hours when a pediatric radiologist was unavailable
- Approximately 40 residents (PGY2-PGY5) and 40 non-pediatric subspecialty attending radiologists interpreted >90% of the examinations
- The primary focus was to identify key findings of appendicitis and alternative explanations for the patient's symptoms on MRI
- A key component of instituting the protocol was training non-expert radiologists and residents

- Many methods (figure 3) were also employed in 2012-2013 to educate surgeons, pediatricians and emergency physicians who were well experienced in CT and not as comfortable with MRI
- As a result, in the initial phases of our protocol, many patient's underwent CT after MRI for confirmation

Methods to Educate Clinicians

Grand Rounds	Departments of Radiology, Emergency Medicine, General and Pediatric Surgery and Pediatrics
Literature	Sharing literature documenting similar accuracy of MRI compared to CT
ALARA Campaign	Robust Image Gently Campaign, fliers, posters, patient education pamphlets
Workstation teaching	Included radiology residents and staff, general surgery residents and pediatricians
Correlation	Interdepartmental radiologic-surgical-pathologic correlation

Figure 3. Methods used at SAMMC to educate other physicians

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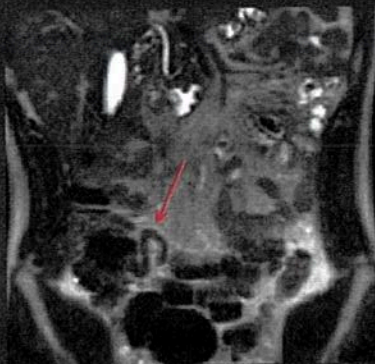
RESULTS

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Physician Education

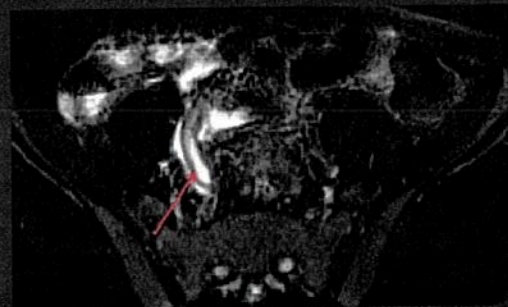
In addition to didactic teaching, direct feedback was also highly effective. We maintained a database of over 500 cases at SAMMC for radiologist review with direct feedback provided to the interpreting radiologist when possible:

- MRI technique (motion, spatial resolution, etc)
- Pathology and surgical reports
- 1 month clinical follow up
- Alternative explanations for patient symptoms
- Good examples of positive and negative cases
- False positives, false negatives



17 year old male with a normal appendix

Coronal HASTE demonstrates a tubular hypodense structure originating from the cecum, measuring 5 mm in diameter. No peri-appendiceal fluid or inflammation.



8 year old male with appendicitis

Axial T2 FS demonstrates a dilated appendix measuring 8 mm with thickened appendiceal wall, intraluminal fluid and peri-appendiceal fluid.

Important concepts used in our exam interpretation

Visualization of the appendix	A normal appendix does not need to be identified to exclude appendicitis. I.e appendix is not seen and there is no free fluid or inflammation = no appendicitis.
Peri-appendiceal inflammation	Present in nearly all cases of acute appendicitis
Appendiceal wall thickening	Circumferential wall thickening >2 mm was nearly always present in acute appendicitis
Small amount of free-fluid and appendix is not visualized	Appendicitis unlikely. May be physiologic or secondary to alternative pathology (ovarian, gastroenteritis, etc)
Appendiceal tip	If RLQ fluid or inflammation, should visualize full appendiceal length to exclude tip appendicitis
Size	Appendix was considered dilated when >6mm; however, size is not a standalone criteria as the appendix may be enlarged without inflammatory changes
Alternative pathology	Assessing for alternative pathology is critical

Figure 4. MR Findings that support or disfavor the diagnosis of appendicitis

Protocol Efficiency

- We compared the time parameters of the first 50 and last 50 rapid MRI exams performed at SAMMC for suspected appendicitis
- Interval changes between first and last exam
 - Abdominal radiograph removed from initial protocol
 - Radiologist reviews US images and determines immediately if MRI is warranted. If so, the patient is sent directly to the MRI Suite
 - Female patient no longer required to fill their bladder (for ovarian evaluation) resulting in decreased ER wait time
 - Decreased number of MR sequences from 7 to 3



8 year old male with appendicitis

Left: Coronal HASTE image demonstrating a dilated fluid filled appendix.

Right: Axial T2 FS image demonstrating a thickened T2 hyper intense edematous appendiceal wall (arrows) with intraluminal T2 hyper intense fluid

Time Parameter Comparison Between the First 50 and Last 50 Rapid Appendicitis MRI Exams

	First 50 Exams	Last 50 Exams
Average number of sequences	7	3
Average repeated sequences	1.2	<1
US Duration	22 Minutes	12 minutes
MRI scanning duration	21 minutes	11 minutes
US Start to MRI Finish	420 minutes	65 minutes

Figure 5. MRI Time Considerations

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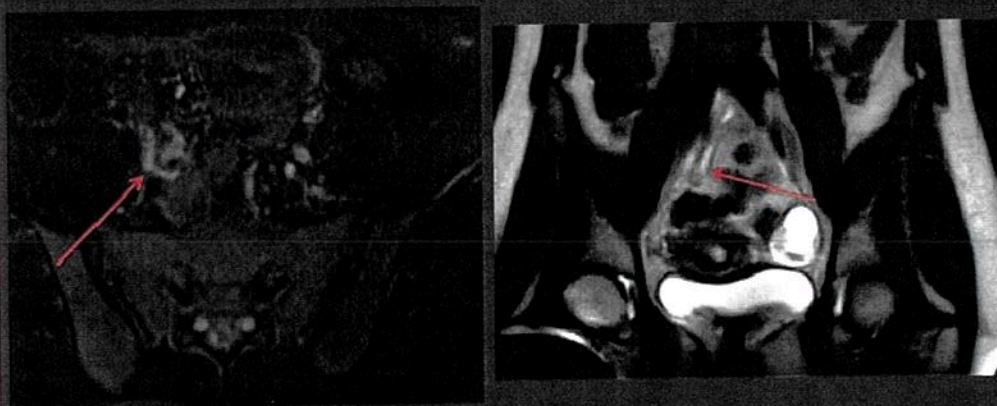
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Statistical Analysis

506 patients* clinically suspected of having appendicitis aged 17 years or younger with equivocal ultrasound (or non-visualization of the appendix) underwent rapid MRI appendicitis imaging at SAMMC between April 2012 and Dec 2015.

* 6 cases were equivocal on MRI and were not included in the statistical analysis. These patients were admitted for observation and all were discharged without acute appendicitis



16 year old female with tip appendicitis.

Left: Axial T2 FS images demonstrate a dilated appendiceal tip with appendicolith and inflammation (arrow)

Right: Coronal HASTE demonstrating a dilated appendiceal tip (arrow)

MRI was classified as either positive or negative

Positive

- MRI findings consistent with appendicitis
- MRI secondary signs of appendicitis (e.g. free fluid with right lower quadrant, inflammation and no appendix visualized)

Negative

- Normal MRI appearance of the appendix
- Appendix not visualized but no secondary signs of appendicitis (inflammation or free fluid)

11 % of all patient's suspected of having appendicitis were true positives (confirmed by surgery or pathology).

		95% CONFIDENCE INTERVAL
Sensitivity by MRI	96%	87.02-99.54
Specificity by MRI	98%	96.21-99.08
Positive Predictive Value	85%	73.43-92.90
Negative Predictive Value	100%	98.37-99.94

Figure 6. Statistical Analysis

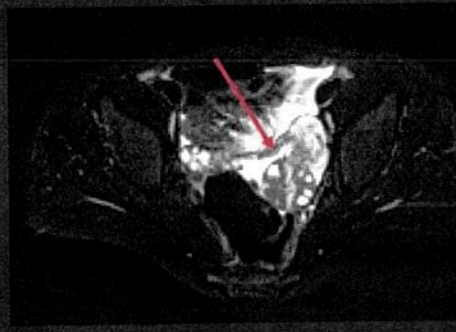
Alternative Diagnoses

- Our exams proved useful in assessing alternative causes for the patients' clinical presentation. And many abnormalities would be more difficult to interpret on ultrasound or CT
- Several non-appendiceal abnormalities were found to likely explain the patients' symptoms
- All patients' records were reviewed for 1 month following discharge to determine if any any patients returned with appendicitis



7 year old female with terminal ileitis

Axial T2 FS demonstrates circumferential thickening of the terminal ileum (arrow)



5 year old female with ovarian torsion

Axial T2 FS demonstrates an enlarged left ovary with peripheralization of the follicles and pelvic free fluid

Non-appendiceal abnormalities

Ovarian Pathology	3%
Pyelonephritis	2%
Rectus Abdominus Edema/Tear	1%
Terminal Ileitis	3%
Pneumonia	1%
Other findings (mesenteric adenitis, cholelithiasis, large stool burden, UTI, Right hip osteonecrosis, right inguinal hernia)	11%

Figure 7. *Alternative diagnoses.*

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Conclusions

1. MRI is an effective imaging modality for the evaluation of pediatric appendicitis and can be accurately interpreted by non-pediatric radiologists.
2. Because of the lack of ionizing radiation and IV contrast, non-sedated, rapid MRI may be considered more appropriate than CT in the pediatric population, which is at higher risk for radiation-induced malignancies and also has less tolerance for IV placement.

3. Clear communication with training of radiology residents, non-pediatric radiologists, clinicians and pediatric radiologists is paramount in guaranteeing the success of MRI in a predominantly adult medical center.

James D Covelli, MD
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INTRODUCTION

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References

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